APPENDIX A. JSC PHOTOGRAPHIC ANALYSIS SUMMARY

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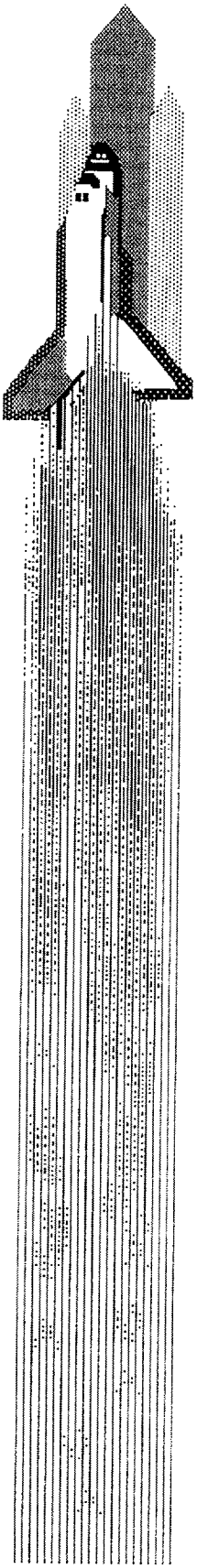

Space Science Branch

STS-101 Summary of Significant Events

July 6, 2000

image science & analysis group
nasa-jsc

Space Shuttle
STS-101 Summary of Significant Events

Project Work Order - SN3CS

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1. STS-101 (OV-104): FILM/VIDEO SCREENING AND TIMING SUMMARY

1.1 SCREENING ACTIVITIES

1.1.1 Launch

The STS-101 launch of Atlantis (OV-104) from Pad 39A occurred on Friday, May 19, 2000 at approximately 140:10:11:10.003 UTC as seen on camera E9. SRB separation occurred at approximately 10:13:13.66 UTC as seen on camera ET207.

On launch day, 24 of the 24 expected videos were received and screened.

Twenty launch films were screened and a report was sent to the Shuttle Program distribution on May 23, 2000. Twenty-three additional films were received for contingency support and anomaly resolution.

A white-colored flash or streak was seen near the Orbiter right wing at approximately 34 seconds MET during the review of the STS-101 ascent videos and films. On the E224 camera film view, a white-object was (possibly) seen contacting the right wing at 34 seconds MET. A summary of similar ascent events since STS-26R was provided to the MER manager prior to landing. After the STS-101 landing, moderate tile damage was found on the undersurface of the Orbiter wing.

Other than the white-colored flash at 34 seconds MET, no anomalous events were seen.

Umbilical well cameras flew on OV-104 during STS-101. Photography of the left SRB, the LSRB/ET aft attach, and the External Tank (ET-92) aft dome was acquired using umbilical well camera films during SRB separation. Umbilical well camera photography of the External Tank (ET) was also acquired during ET separation and handheld still photography/video of the ET was acquired following separation.

Video (acquired from cameras mounted on the SRB forward skirts) of the External Tank's +Y and –Y thrust panels was acquired during ascent on STS-101.

1.1.2 On-Orbit

No unplanned on-orbit Shuttle analysis support was requested. Pre-planned real-time analysis support was provided to the ISS AF-2A.2A Space Station photographic and television external survey. The Space Station image analysis support will be documented in the AF-2A.2A Imagery Overview Report. (No post-mission report was requested.)

1.1.3 Landing

Atlantis made a night landing on runway 15 at the KSC Shuttle Landing Facility on May 28, 2000 at 06:20:17.96 UTC. Ten videos and ten films were received.

The landing touchdown appeared normal. No anomalous events were seen during the Orbiter approach, landing, and landing roll-out.

Post landing, a sink rate analysis of the STS-101 main landing gear was performed for the main gear touchdown.

The drag chute deploy sequence appeared normal on the landing imagery. Flames from the APU vent located at the forward edge of the base of the vertical stabilizer were seen during the landing roll out and after wheel stop. Flames from the APU during landing have occurred on previous missions.

According to the pre-mission agreement, the STS-101 landing films were not screened due to budgetary constraints.

1.2 LANDING EVENTS TIMING

The time codes from videos were used to identify specific events during the screening process. The landing event times are provided in Table 1.2.

STS-101 Landing and Drag Chute Event Times from Video

Event Description	Time (UTC)	Camera
Main gear door opening	No Timing	EL17IR
Right main gear inboard tire touchdown	150:06:20:17.96	SLF N
Left main gear tire touchdown	150:06:20:17.99	SLF N
Drag chute initiation	150:06:20:21.99	KTV15L
Pilot chute at full inflation	150:06:20:22.95	KTV33L
Bag release	150:06:20:23.52	KTV33L
Drag chute inflation in reefed configuration	150:06:20:24.62	KTV33L
Drag chute inflation in disreefed configuration	150:06:20:28.56	KTV33L
Nose gear tire touchdown	150:06:20:29.26	KTV33L
Drag chute release	~150:06:20:57.0	KTV33L
Wheel stop	~150:06:21:13.7	KTV33L

Note: The symbol ~ means that the event was not clearly seen because of the limited light available during the night landing and the event time shown is approximate.

Table 1.2 Landing Event Times

2. SUMMARY OF SIGNIFICANT EVENTS

2.1 DEBRIS FROM SSME IGNITION THROUGH LIFTOFF

Multiple pieces of ice debris and vapors were seen falling from the ET/Orbiter umbilicals along the –Z side of the body flap during SSME ignition.

Vapor and ice debris were seen falling from the ET side of the 4-inch LH2 recirculation line and white-colored debris (probably ice) was seen falling from an unidentified area forward of the –Y aft ET attach (10:11:06.210 UTC). None of the debris was seen to contact the vehicle. (Cameras OTV009, OTV054, E1, E4, E5, E17, E19, E31, E34, E36)

Figure 2.1(A) Ice Contacting SSME #3 Engine Bell

A large, single piece of white-colored debris (ice) from the LO2 TSM T-0 disconnect fell aft and contacted the SSME #3 engine bell at the number 8 hatband forward of the SSME #3 rim prior to the SSME Mach diamond formation (10:11:06.438 UTC). See Figure 2.1(A). A second piece of debris contacted the SSME #3 engine bell forward of the rim during SSME ignition (10:11:06.636 UTC). A large, white-colored, vaporous cloud from the LO2 TSM T-0 disconnect was seen near SSME #3 at 10:11:10.9 UTC. No damage to the SSME #3 engine bell was detected. (Cameras OTV051, OTV070, OTV071, E19, E76)

On camera E1, two light-colored pieces of debris were seen being ejected from the flame trench and arc forward toward the main engines during SSME ignition. On camera E19 (possibly the same event), a single, irregular-shaped, dark-colored piece of debris was seen near SSME #3 during SSME ignition. (10:11:06.681 UTC). On camera E5, two pieces of light-colored debris were seen being ejected from the flame trench and traveling in an upward direction near the –Z side of the body flap prior to liftoff (10:11:08.890 UTC). SRB flame trench debris was seen moving northward away from the vehicle at liftoff (10:11:11.432 UTC). This debris was not seen to contact the launch vehicle. (Cameras E1, E4, E5, E19, E36, E52)

White-colored vapor (probably condensation) was seen to originate from the +Y ET vertical strut attach area during SSME ignition. A single piece of ice debris fell aft and contacted the forward surface of the ET +Y vertical strut (10:11:06.987 UTC). Pieces of light-colored debris were seen falling from the –Y ET vertical strut attach during SSME ignition (10:11:05.54, 10:11:06.210 UTC). No damage was detected. (Cameras OTV054, OTV063, E5, E31)

Figure 2.1(B) Orange-Colored Debris Seen after SSME Ignition

A single, orange-colored, linear-shaped, flexible appearing object (possibly a piece of umbilical purge barrier tape) fell aft along the –Z side of the body flap after SSME ignition (10:11:08.876 UTC). See Figure 2.1(B). (Camera E18)

A red-colored, rectangular-shaped piece of unidentified debris (possible RCS paper) was seen falling aft near the base of SSME #2 and SSME #3 during SSME ignition (10:11:06.311 UTC). (Camera E19)

Figure 2.1(C) Debris Traveling Westward from the Launch Pad

A large light-colored rectangular-shaped piece of debris was seen during liftoff traveling westward from the launch pad. See Figure 2.1(C). KSC reported that the debris might be a panel from the RSS. This debris did not appear to be in close proximity to the launch vehicle. (Camera KTV21A)

A single light-colored piece of debris was seen moving from the –Y side of the launch vehicle and fell aft near the LSRB during liftoff (10:11:12.476 UTC). The debris was not seen to contact the vehicle. (Camera E4)

2.2 DEBRIS DURING ASCENT

Debris typical of that seen on previous missions were seen aft of the launch vehicle during ascent:

Multiple pieces of debris (umbilical ice and RCS paper debris too numerous to count) were seen falling aft of the launch vehicle during ascent. Orange-colored ET/Orbiter umbilical purge barrier material debris were seen aft of the body flap (10:11:25.9 and 10:11:40.6 UTC). A spray of light-colored debris (probably forward RCS paper) was seen near the trailing edge of the vertical stabilizer at 10:11:26.446 UTC. Forward RCS

paper debris, first seen near the right OMS pod, fell aft producing a flare in the SSME exhaust plume.

Figure 2.2(A) Flare Seen in SSME Exhaust Plume

A piece of RCS paper debris was seeing falling from a region near the left RCS stinger, moving across the +Z side of SSME #1, past the –X side of SSME #2, and traveling aft into the SSME exhaust plume resulting in a large orange-colored debris-induced flare (10:12:03.2 UTC). See Figure 2.2(A). Other smaller flares in the SSME exhaust plume (probably debris induced) were also seen during ascent (10:11:46.4, 10:11:54.2 UTC). Furthermore, debris was seen near the SRB exhaust plume during ascent (10:11:11.35, 10:11:45.2, 10:12:13.9, 10:12:23.5, 10:12:24.2, 10:12:26.9 UTC). (Cameras KTV2, KTV5, KTV4A, ET207, ET212, ET213, E52, E207, E212, E222, E223, E224)

2.3 MOBILE LAUNCH PLATFORM (MLP) EVENTS

Figure 2.3(A) Orange Vapor Seen During SSME Ignition

Extensive orange vapor (possibly free burning hydrogen) was seen forward of the SSME rims, contacting the drag chute door, and extending forward along the base of the vertical stabilizer during SSME ignition (10:11:04.7 UTC). See Figure 2.3(A). Orange vapor forward of the SSME rims has been seen on previous mission films and videos. However, the orange vapor seen on STS-101 was more apparent than the vapors seen on most previous missions. (Cameras OTV051, OTV070, E1, E2, E5, E17, E18, E19, E20, E63, E76)

The SSME ignition appeared normal on the high-speed engineering films and the SSME Mach diamonds appeared to form in the expected sequence (3, 2, 1). The times for the Mach diamond formation given in Table 2.3 are from camera film E19.

SSME	TIME (UTC)
SSME #3	10:11:06.693 UTC
SSME #2	10:11:06.830 UTC
SSME #1	10:11:07.066 UTC

Table 2.3 SSME Mach Diamond Formation Times

A faint, light-colored flash was seen extending aft from the SSME #2 nozzle rim prior to liftoff (10:11:07.784 UTC). (Camera E19)

Two small areas of tile surface coating material erosion were seen during SSME ignition on the base heat shield near the base of the right RCS stinger (11:10:05.438 UTC). At approximately the same time, three small areas of tile surface coating material erosion were seen on the base heat shield inboard of the left downward firing RCS thrusters, and on the base heat shield outboard of SSME #2. Erosion of the tile surface coating material is typically seen on the launch imagery. (Cameras E17, E18)

No indication of holddown post (HDP) stud hang-ups were seen and no debris was seen falling from the HDP stud holes.

Post landing, engineers noted an unusually high frequency response in the strain gage data acquired during launch from RSRB holddown posts M-2 and M-4. This high frequency response was declared an in-flight anomaly (IFA number STS-101-1-01) per Program Requirements Control Board (PRCB) S062139, on June 8, 2000. The RSRB holddown post films were reviewed with engineers from Space Shuttle Systems Integration for unusual motions or debris that might have been associated with the high frequency strain gage readings. However, no anomalous conditions were noted on the films.

PIC firing was timed at 10:11:10.003 UTC on HDP M-1, camera film E9.

2.4 ASCENT EVENTS

The R2R and R3R paper covers on the side firing RCS thrusters did not tear away prior to or during early lift off as is typically seen. Also, the paper covers on the port RCS aft firing thrusters did not tear away. KSC reported that, although unusual, this is not an anomalous event. (Cameras E2, E5, E18)

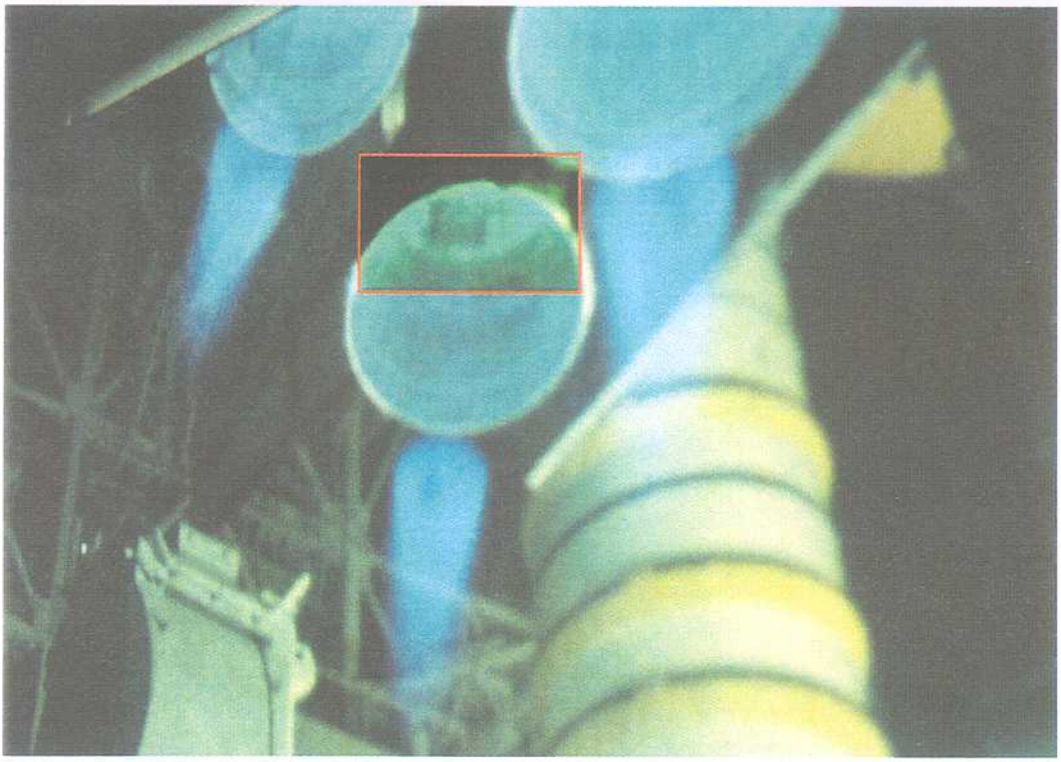


Figure 2.4(A) White-colored Ring Seen inside SSME #2

A white-colored ring was visible on the hot wall inside of the SSME #2 nozzle at liftoff (10:11:11.732 UTC) and during ascent (10:12:22.5 UTC). See Figure 2.4(A). MSFC reported that the SSME #2 hot wall appeared normal on the camera E19 liftoff view. No follow-up action was requested. (Cameras E19, E207, ET207)

On STS-101 ascent, a long white-colored vaporous streak was seen trailing from the right inboard elevon after the roll maneuver at approximately 34 seconds MET (10:11:44.15 UTC). See Figure 2.4(B). Figure 2.4(C) contains a comparison between a similar, but more extensive, streak seen on STS-26R with the streak seen on STS-101. (The streak on STS-26R occurred at approximately 51 seconds MET.) Prior to the STS-101 landing, the MER manager was provided with a summary of the previous Space Shuttle flights with known launch events that could possibly be associated with Orbiter tile damage.

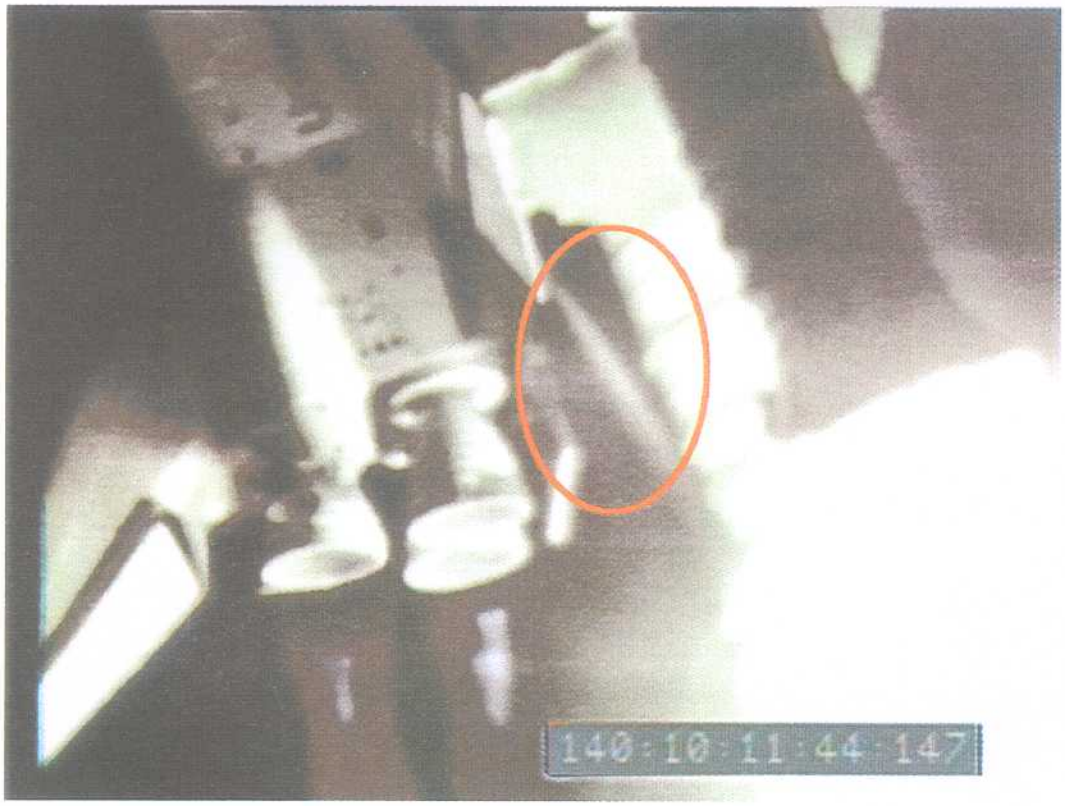


Figure 2.4(B) STS-101 Streak Seen off Starboard Elevon

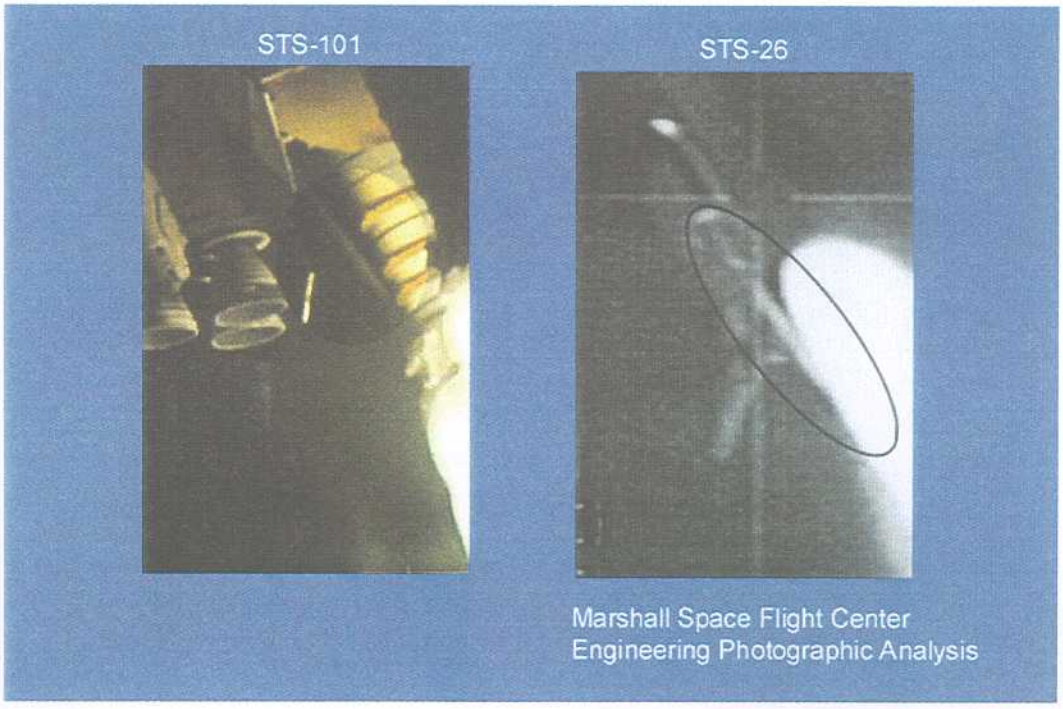


Figure 2.4(C) White-colored Streak at 34 Seconds MET (STS-101) and 51 Seconds MET (STS-26R)

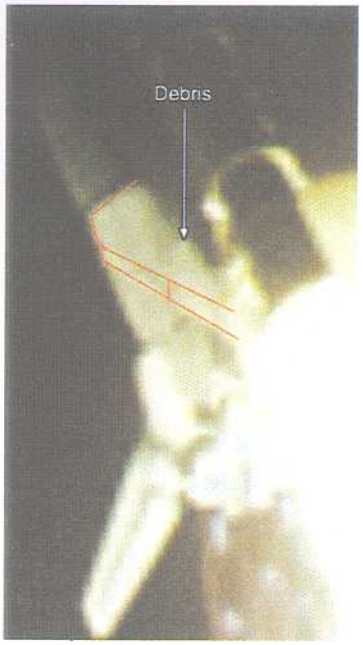


Figure 2.4(D) Possible Debris Contacting Right Wing

On STS-101 camera film E224 (Figure 2.4(D), a white-colored object appeared to (possibly) contact the undersurface of the right wing (outlined in red) immediately prior to the time that the streak was visible on the camera ET207 view shown in Figure 2.4(B). (10:11:44.109 UTC). (Cameras ET207, E207, E224)

Post landing inspections confirmed that tile damage to the underside of the right wing, previously suspected because of the imagery screening, had occurred. However KSC reported that this damage was not a significant concern. The impact site was located about 10 feet in front of the right inboard elevon and measured 5.25-inches long, 1.5-inches wide and 0.5-inch deep. (As a comparison, STS-26R tile damage measured during the post landing inspection was 18 x 6 inches in area and extended 1.5 inches into the upper surface of the right wing). On STS-101, there was no indication of structural damage.

A bright flash from the planned OMS assist burn was seen at the aft end of the launch vehicle approximately eleven seconds after SRB separation (10:13:24.1 UTC). (Cameras ET204, ET207, ET208, E212, KTV13, E212)

White-colored vapor (probably water) was seen streaming from the drain hole at the mid-level of the trailing edge of the rudder speed brake during liftoff and early ascent. This event has been seen on previous missions. (Camera E52)

Body flap motion was seen during ascent with the amplitude and frequency of the motion appearing similar to that seen on previous mission imagery. No follow-up action was requested. (Camera E207)

2.5 ONBOARD PHOTOGRAPHY OF THE EXTERNAL TANK (ET-102)

2.5.1 Analysis of the Umbilical Well Camera Films

16mm Umbilical Well Camera Films

The FL101 (5mm wide angle lens) 16mm umbilical film was not received and was reported by KSC to be a no run. The FL102 (10mm lens) 16mm umbilical well film was received, however, back lighting from the early morning Sun degraded the film quality. Timing data was present on camera film (FL102).

The LSRB separation appeared normal on the 16mm umbilical well camera film. Numerous light-colored pieces of debris (insulation), and dark debris (charred insulation) were seen throughout the SRB separation film sequence. Typical ablation and charring of the ET/Orbiter LH2 umbilical electric cable tray and the aft surface of the -Y upper strut fairing were seen prior to SRB separation. Numerous irregularly shaped pieces of debris (charred insulation) were noted near the base of the LSRB electric cable tray prior to SRB separation. Pieces of TPS were seen detaching from the aft surface of the horizontal section of the -Y ET vertical strut and several small pieces of dark-colored debris were seen near the aft LSRB/ET attach at SRB separation. The amount of ablation of the TPS on the aft dome was typical of previous flights. The SRB nose caps were not seen because of the narrow angle of the 10mm lens and dark shadows.

The ET separation from the Orbiter appeared normal. Typical vapor and multiple light-colored pieces of debris (frozen hydrogen) were seen almost continuously before, during, and after the umbilical separation.

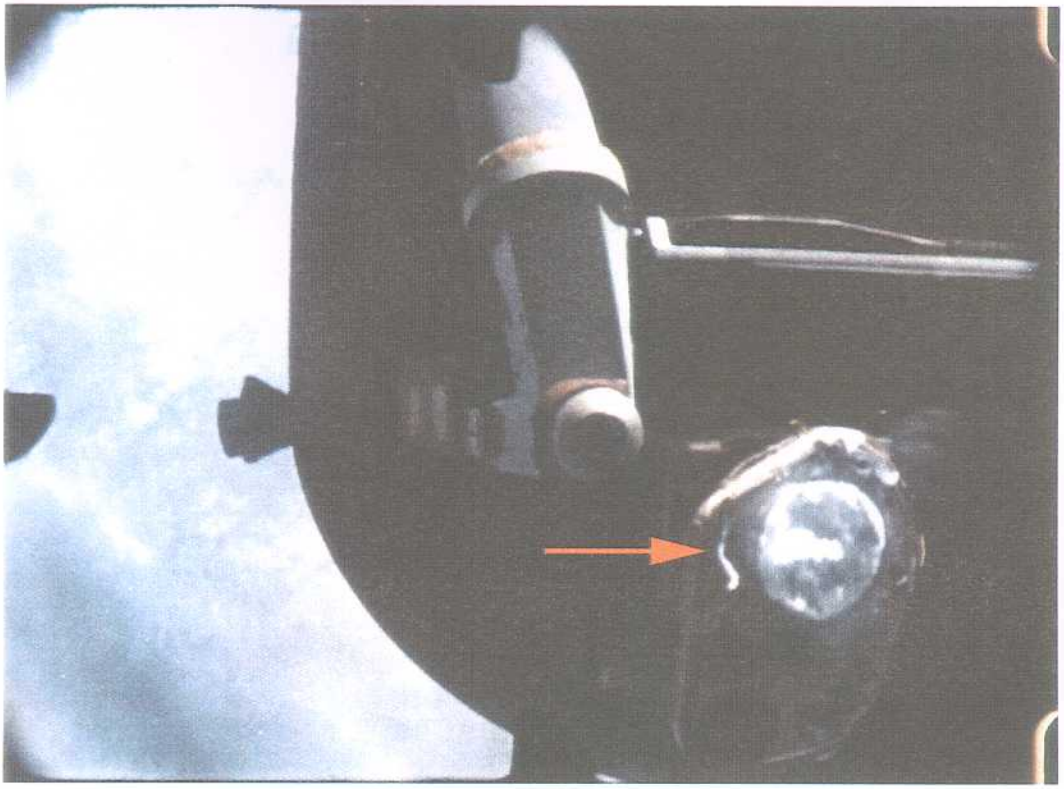


Figure 2.5.1(A) Detached Purge Seal on Face of LH2 Umbilical

Most of the face of the ET/Orbiter LH2 umbilical was obscured by shadows during the separation of the ET from the Orbiter. However, a forward outboard portion (~9 o'clock position on the face of the LH2 umbilical) of the white-colored purge seal was seen to be partially detached and extending outward toward the camera (+Z direction). See Figure 2.5.1(A). As typically seen on previous missions, frozen hydrogen was visible on the orifice of the LH2 17 inch connect and near the 1 o'clock position of the LH2 umbilical and the –Y end of the ET cross beam. The red-colored purge seal on the EO-2 ball joint fitting appeared to be in place.

The +Z and –Y aspects of the LH2 tank, intertank, and Ojive were in shadow and too dark for analysis. The -Y ET thrust panel was in shadow and too dark for analysis. However, the portions of the +Z/+Y LH2 tank, intertank, and Ojive (including the LO2 feedline, press lines, cable trays, and ramps) that were visible appeared in good condition.

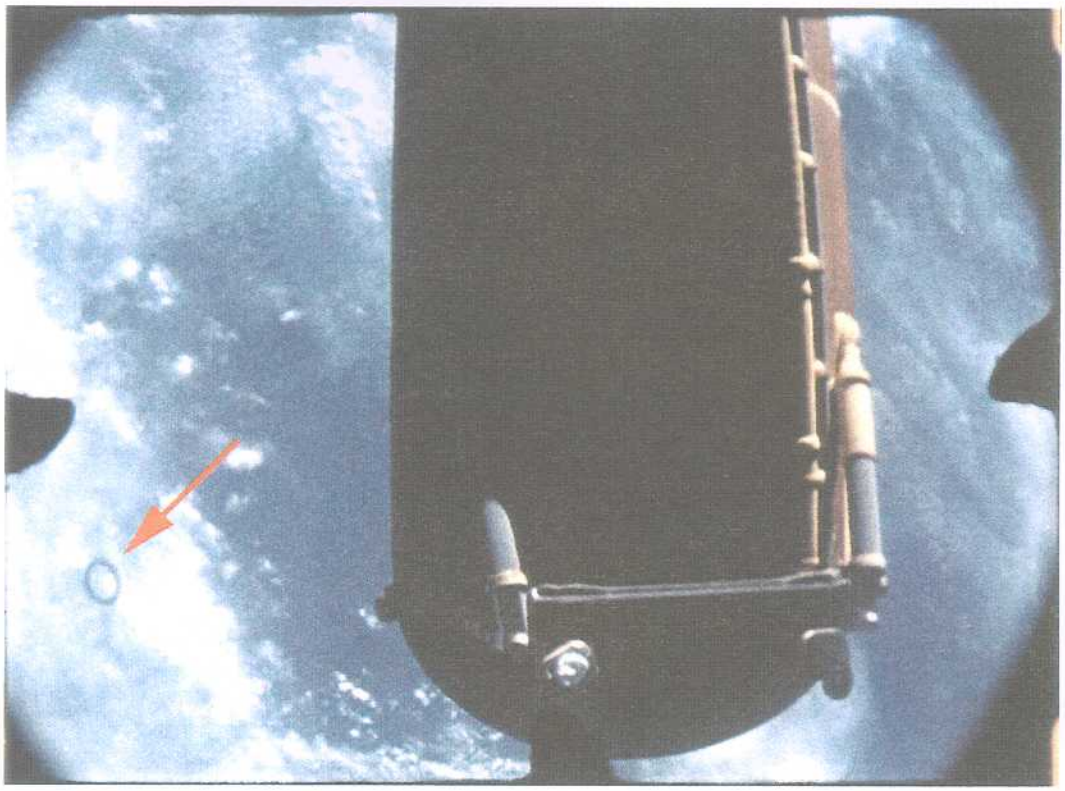


Figure 2.5.1(B) Unidentified Debris

On frames 7819 through 7900, a circular-shaped debris object was seen tumbling aft along the left side of the field of view. See Figure 2.5.1(B). The object appeared close to the camera and had a large inner diameter. KSC reported that the object might be an O-ring rather than a washer.

35mm Umbilical Well Camera Film

The +X translation maneuver was performed on STS-101 to facilitate the imaging of the ET with the umbilical well cameras. However MOD reported that the +X maneuver was started late resulting in the nose of the ET not being recorded on the 35mm umbilical well camera film (roll 404). Sixty frames imaging the ET were acquired. The film quality is excellent. However, the left side of the view (+Z / -Y axis of the ET) is obscured by shadow and is too dark for analysis. Frames 54 through 60 were camera run-down frames (typically seen) and have an orange-colored tone rather than normal color tones.

Based on the screening of the close-up 35mm umbilical well camera film, the visible portions of the ET appeared to be in good condition after the separation from the Orbiter.

The un-shadowed, visible portion of the +Z/+Y LH2 tank TPS appeared to be in excellent condition. A possible area of minor LH2 tank TPS erosion was seen in the +Y direction from the +Y longeron at approximately station XT-1900 that was not visible on the pre-launch closeout photography. However, the color and tone of these marks is similar to

older pre-launch repair marks indicating that no additional TPS coating was lost during ascent.

Figure 2.5.1(C) +Z/+Y ET Intertank

The visible portion of the +Z/+Y ET Thrust Panel appeared in excellent condition. No divots were noted on the rib heads of the +Y ET thrust panel TPS. As expected, the left (-Y) SRB thrust panel was not imaged on this film.

The LH2 tank-to-intertank flange closeout between the legs of the forward ET/Orbiter attach bipod could not be seen because of the dark shadow. (A possible divot was seen at this location on the fully illuminated handheld photography).

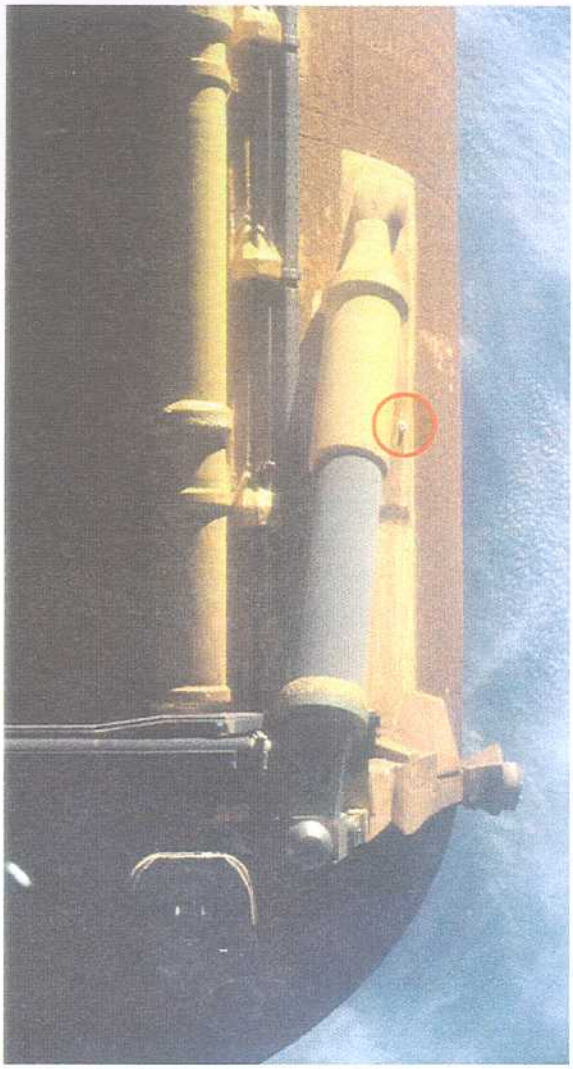


Figure 2.5.1(D) White-colored Object on +Y Longeron

A small, square-shaped, white-colored object that appears to be ice / frost or possibly a piece of up-lifted TPS was seen near the mid level of the +Y longeron at approximately station XT-1980. See Figure 2.5.1(D). KSC reported that a hairline crack was noted on this area of the +Y longeron during cryo-loading.

A small, square-shaped, white-colored mark (possible shallow divot) was seen on the –Y end of the +Y vertical strut at approximately station XT-2030.

Minor TPS chipping and very small divots (typical of previous missions) were seen on the aft LO2 feedline flanges and on the aft bracket over the press lines. Small, shallow areas of TPS erosion and divoting were visible on the aft flange of the +Y ET/Orbiter thrust strut. Typical ablation and divoting of the TPS on the vertical section of the +Y electric cable tray adjacent to the LO2 umbilical were detected. The ET aft dome was obscured by shadow.

The face of the LO2 umbilical carrier plate, although mostly in shadow, appeared to be in excellent condition (no indication of damaged or missing lightning contact strips was detected).

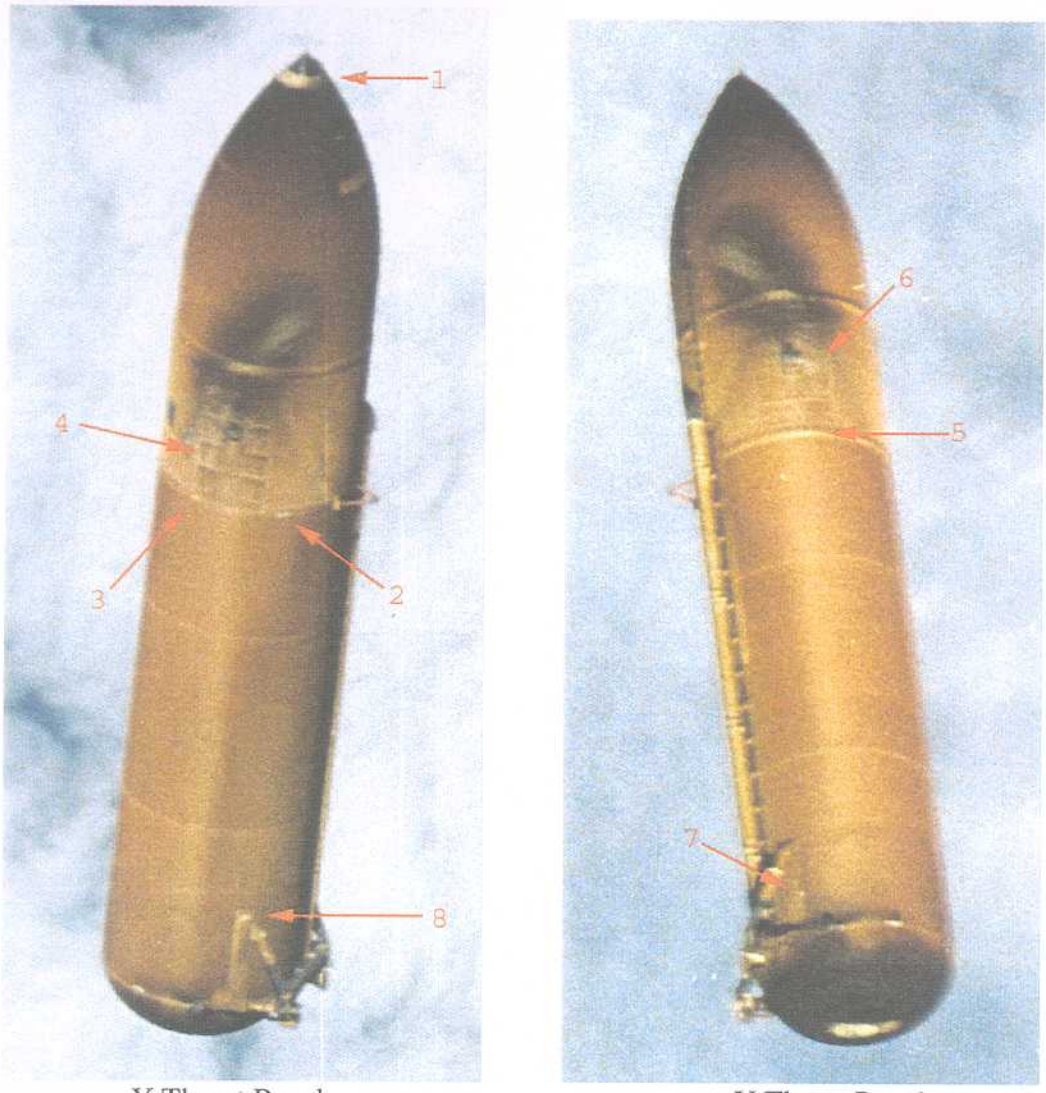
The visible portion of the red-colored purge seal on the EO-3 ball joint fitting appeared to be in place.

2.5.2 ET Handheld Photography

The STS-101 handheld pictures of the External Tank (ET-102) are excellent in quality. The ET was fully illuminated with very little shadowing. Timing data is present on the film with the first picture being taken at 16:35 (minutes:seconds) MET. The distance of the ET from the Orbiter was calculated to be approximately 2.3 km on the first photographic frame acquired. At this distance, objects (damage) smaller than seven to eight inches in size are not detectable. The separation velocity of the ET from the Orbiter was estimated to be 7.4 m/sec.

The astronauts performed a manual pitch maneuver from the heads-up position to bring the ET into view in the Orbiter overhead windows for the handheld photography. (STS-101 was the tenth flight using the roll-to-heads-up maneuver).

Thirty-five images of the ET were acquired using the handheld 35mm Nikon F5 camera with a 400mm lens (roll 382). Views of the nose, the aft dome, the side of the ET facing the Orbiter (+Z), and both limbs (+/– Y sides) of the ET were obtained. The far side (-Z) of the ET was not imaged.



-Y Thrust Panel +Y Thrust Panel

Figure 2.5.2(A) Handheld ET Views

The normal SRB separation burn scars and aero-heating marks were noted on the intertank and nose TPS of the ET. See Figure 2.5.2(A). In addition, the following items were noted:

- A band of eroded TPS (and possible divots) was seen just aft of the ET nose cap. (Figure 2.5.2(A) annotation #1)

- Two light-colored marks (divots), approximately 9-inches in diameter, are visible in the direction of the left (-Y) limb of the ET on the LH2 tank-to-intertank flange closeout between the bipod and the –Y thrust panel. (Figure 2.5.2(A) annotation #2)

- A light-colored mark (divot), approximately 9-inches in size was seen near the LH2 tank-to-intertank flange at the aft –Y corner of the –Y thrust panel. (Figure 2.5.2(A)

annotation #3) (On the LSRB thrust panel video, this divot appeared to be in the LH2 tank TPS adjacent to the flange close-out.)

• Three large appearing light-colored areas were noted on the –Y thrust panel in the –Y direction from the LSRB forward attach fitting. (On the LSRB thrust panel video, there is an indication of possible small divots on several rib heads in one of these three areas that could be seen during SRB separation.) (Figure 2.5.2(A) annotation #4)

• Two light-colored marks were detected on the +Y LH2 tank-to-intertank flange close out aft of the forward RSRB attach fitting. (Figure 2.5.2(A) annotation #5) This portion of the LH2 tank-to-intertank flange close out was imaged on the close-up RSRB thrust panel video during ET separation. However, no indication of TPS erosion or divots was seen on the close up video.

• Three light-colored areas were detected on the +Y thrust panel in the +Y direction from the RSRB forward attach fitting. These light-colored areas may be caused by areas of TPS erosion or clusters of divots too small to resolve on the handheld film. (Figure 2.5.2(A) annotation #6)

• A light-colored mark (possible divot) was seen on the +Y longeron (Figure 2.5.2(A) annotation #7). This may be the white-colored object visible on the 35mm umbilical well camera film circled on Figure 2.5.1(D).

• A light-colored mark (possible divot) was seen on the forward left corner of the –Y longeron. (Figure 2.5.2(A) annotation #8)

The area of divots seen in the unvented area aft of station 1013 on the RSRB thrust panel seen on the higher resolution, close-up, SRB thrust panel video was not detected on the handheld photography. (These divots were estimated to be less than 5-inches in size on the video which is below the estimated resolution seen on the handheld film.)

Figure 2.5.2(B) Handheld ET Views – Debris Seen between Legs of Forward Bipod

• A light-colored mark (divot), approximately 8 to 9-inches in size, is visible on the LH2 tank-to-intertank flange closeout between the legs of the forward bipod. (Figure 2.5.2(B))

(Venting from the ET intertank region was not seen on the STS-101 handheld film. However, venting was seen on the handheld video).

2.5.3 ET Handheld Video

The crew handheld video of the ET was acquired on STS-101. However there was no timing data on the video. Venting from the ET intertank region was seen on the crew handheld video.

Table 2.5.3 contains a comparison of the averaged tumble rate(end-to-end rotation of the ET about its center of mass) measurements for the current and eight previous Space Shuttle missions.

MISSION	Tumble Rate (deg/sec)	Separation Rate (m/sec)	MET (mm:ss)	Venting
STS-87	11	--	17:23 - 18:08	Yes
STS-89	12	--	31:42 - 35:27	Yes
STS-90	3	--	14:30*	Yes
STS-91	11	--	16:29 - 18:46	Yes
STS-95	< 1	5.5 (prior to venting)	13:40 - 20:50	Yes
STS-88	2	6.2	15:39 - 22:44	No
STS-96	1.3	6.5	13:21 – 18:21	No
STS-93	14.7	Not Determined	28:56 - 32:56	No
STS-103	--	Not Determined	--	--
STS-99	--	5.8	21:14 – 22:31	Yes
STS-101	**5.8 (pre-vent) 6.9 (post-vent)**	**7.4**	**No Timing**	**Yes**

Only the first four frames had timing data (on STS-90 photography). Relative time from video was used to determine the STS-90 tumble rate.

Table 2.5.3 ET Tumble and Separation Rates

Venting from the ET intertank region has been seen on six (recently flown) previous missions (STS-87, STS-89, STS-90, STS-91, STS-95, STS-99).

2.6 ET THRUST PANEL VIDEO

The left and right SRB thrust videos are excellent in quality with good exposure and focus. As on the previous mission thrust panel video, the divots began to form after approximately 100 seconds MET. As before, there were smaller and fewer divots in the vented areas of the thrust panels compared to the non vented areas. Most of the divots were shallow and less than 0.5-inches in size. No primed substrate was detected. There was a greater number of divots visible on the right SRB thrust panel compared to the left SRB thrust panel.

Left SRB Thrust Panel Right SRB Thrust Panel

Figure 2.6 (A) ET Thrust Panel Views Prior to Separation

Figure 2.6(A) contains views of the STS-101 ET Thrust Panels just before SRB separation (2:03 seconds MET). After separation, there were a large number of divots visible in the unvented area of the right ET thrust panel aft and in the -Y direction from the RSRB attach fitting (area outlined in red on the right SRB thrust panel view). The largest of these divots were estimated to be less than 5-inches in diameter. Six divots were seen on a right thrust panel circumferential rib (station XT-1058). A seventh divot was seen on the same circumferential rib in the +Y direction closer to the +Y intertank.

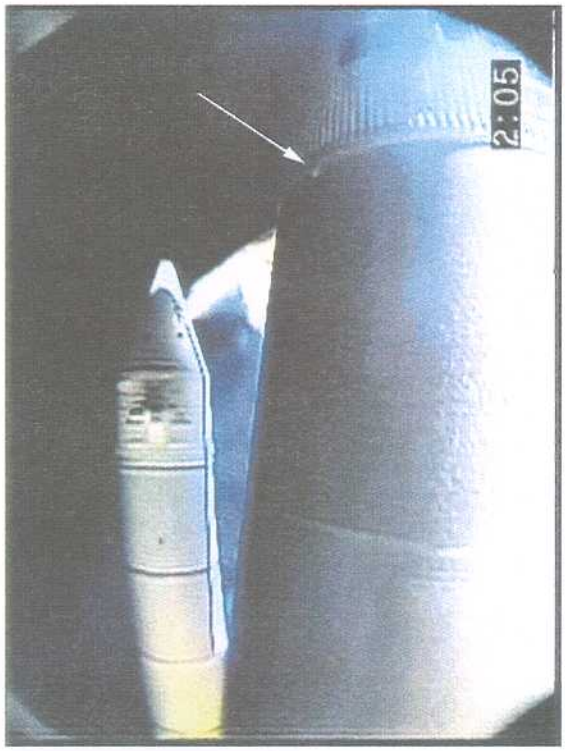


Figure 2.6(B) Divot on –Y LH2-to-intertank Flange Closeout

An approximate 9-inch divot was seen on the -Y LH2-to-intertank flange closeout and the LH2 tank interface aft of the intertank access door (Figure 2.6(B).

Several small divots were seen on the +Y/-Z intertank rib heads during the SRB separation. Multiple pieces of small white-colored debris were seen moving throughout the field of view during SRB separation on both of the thrust panel video views.

Based on a visual comparison between the STS-101 views and the previous mission STS-103 thrust panel video, both of the STS-101 thrust panels appeared to contain more visible divots than the STS-103 video views of the respective thrust panels.

2.7 LANDING SINK RATE ANALYSIS

Image data from the centerline film camera at the approach end of runway 33 was used to determine the landing sink rate of the main gear. In the analysis, data from approximately one second of imagery immediately prior to touchdown was considered. Data points defining the main gear struts were collected on every frame (101 frames of the data during the last second prior to touch down). An assumption was made that the line of sight of the camera was perpendicular to the Orbiter's y-axis. The distance between the main gear struts was used as a scaling factor. The main gear height above the runway was calculated by the vertical difference between the main gear struts and a reference point on the runway. A trendline was determined considering the height of the Orbiter above ground with respect to time. The sink rate equals the slope of this regression line.

The left main gear sink rate for STS-101 landing at one second, at half a second, and at a one quarter of a second are provided in Table 2.7. A plot describing these sinkrates is shown in Figure 2.7.

Time Prior to Touchdown	Left Main Gear Sink Rate	Estimated Error (1σ)
1.00 Sec.	1.9 ft/sec	± 0.1 ft/sec
0.50 Sec.	2.2 ft/sec	± 0.1 ft/sec
0.25 Sec.	2.8 ft/sec	± 0.2 ft/sec

Right Main Gear Touchdown = 150:06:20:17:960 (UTC)

Table 2.7 Main Gear Landing Sink Rate

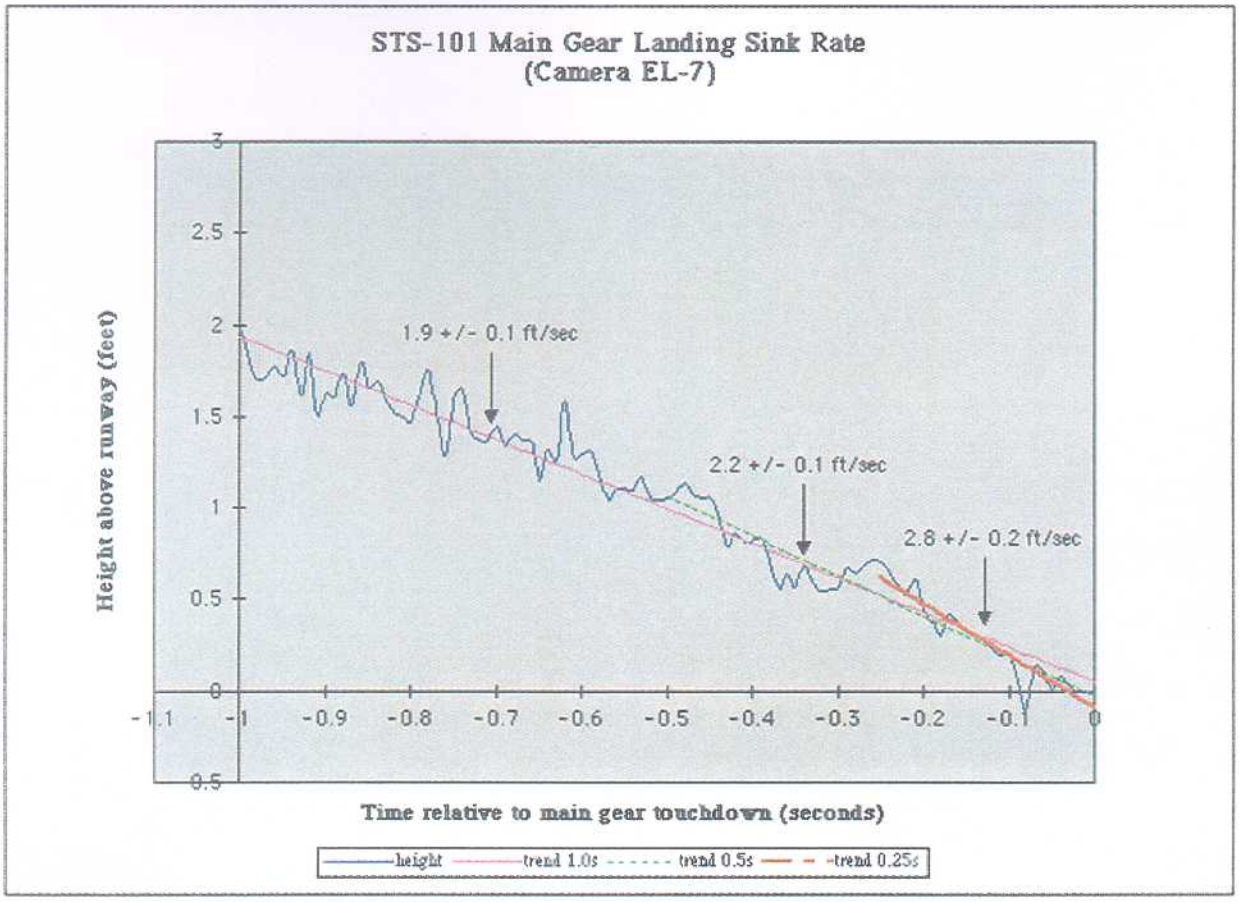


Figure 2.7 Main Gear Landing Sink Rate

The maximum allowable main gear sink rate values are 9.6 feet/second for a 212,000 lb. vehicle and 6.0 feet/second for a 240,000 lb. vehicle. The landing weight of the STS-101 vehicle was estimated to be 226,131 lbs.

2.8 OTHER

2.8.1 Normal Events

- elevon motion prior to liftoff
- RCS paper debris from SSME ignition through liftoff
- ET twang
- ice and vapor from the LO2 and LH2 TSM T-0 umbilical prior to and after disconnect
- multiple pieces of ET/Orbiter umbilical ice debris falling along the body flap during liftoff
- vapor off the SRB stiffener rings
- acoustic waves in the exhaust cloud during liftoff

- debris in the exhaust cloud after liftoff
- expansion waves after liftoff
- charring of the ET aft dome
- ET aft dome outgassing
- roll maneuver
- linear optical effects
- recirculation
- SRB plume brightening
- SRB slag debris before, during, and after SRB separation

2.8.2 Normal Pad Events

Normal pad events observed included:

- hydrogen burn ignitor operation
- FSS and MLP deluge water activation
- sound suppression system water operation
- GH2 vent arm retraction
- TSM T-0 umbilical operations
- LH2 and LO2 TSM door closures